



P H I L O S O P H I C A L
T R A N S A C T I O N S.

XIX. *On the remarkable Appearances at the Polar Regions of the Planet Mars, the Inclination of its Axis, the Position of its Poles, and its spheroidal Figure; with a few Hints relating to its real Diameter and Atmosphere.* By William Herschel, Esq. F. R. S.

Read March 11, 1784.

WHAT I have to offer on the subject of the remarkable appearances at the polar regions of Mars, as well as what relates to the inclination of the axis, the position of the poles, and the spheroidal figure of that planet, is founded on a series of observations which I shall deliver in this paper; and

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after

after they have been given in the order they were made, it will be easy to shew, by a few deductions from them, that my theory of this planet is supported by facts which will sufficiently authorise the conclusions I have drawn from them. For the sake of better order and perspicuity, however, I shall treat each subject apart, and begin with the remarkable appearances about the polar regions. The observations on them were made with a view to the situation and inclination of the axis of Mars; for to determine these we cannot conveniently use the spots on its surface, in the manner which is practised on the sun. The quantities to be measured are so small, and the observations of the center of Mars so precarious, and attended with such difficulties (since an error of only a few seconds would be fatal) that we must have recourse to other methods.

When I found that the poles of Mars were distinguished with remarkable luminous spots *, it occurred to me, that we might obtain a good theory for settling the inclination and nodes of that planet's axis, by measures taken of the situation of those spots. But, not to proceed upon grounds that wanted confirmation, it became necessary to determine by observation, how far these polar spots might be depended upon as permanent; and in what latitude of the globe of Mars they were situated; for, if they should either be changeable, or not be at the very poles, we might be led into great mistakes by overlooking these circumstances. The following observations will assist us in the investigation of these preliminary points.

* A bright spot near the southern pole, appearing like a polar zone, has also been observed by M. MARALDI. See Dr. SMITH's Optics, § 1094.

1777, April 17. 7 h. 50'. There are two remarkable bright spots on Mars. In fig. 1. tab. VI. they are marked *a* and *b*. The line AB expresses the direction of a parallel of declination. 10 feet reflector, 9 inches aperture, power 211 *.

10 h. 20'. They are both quite gone out of the disk.

1779, This year, in all my observations on Mars, there is no mention of any bright spots, so that I believe there were none remarkable enough to attract my attention. However, as my view was particularly directed to the phænomena of this planet's diurnal rotation, it is possible I might overlook them.

1781, March 13. 17 h. 40'. 20 feet reflector. I saw a very lucid spot on the southern limb of Mars of a considerable extent. See fig. 2.

June 25. 11 h. 36'. 7 feet reflector, power 227. Two luminous spots appeared at *a* and *b*, fig. 3.; *a* is larger than *b*.

12 h. 15'. With 460. *a* is thicker than *b*, but *b* is rather longer.

13 h. 12'. *a* is grown thicker, and *b* become thinner.

June 27. 11 h. 20'. The two lucid spots are on Mars.

June 28. 11 h. 15'. They are both visible; *a*, fig. 4. is much thicker than *b*.

12 h. 55'. A line joining *a* and *b* does not go through the center.

June 30. 10 h. 48'. The spot *a* is visible. fig. 5.

11 h. 35'. Both spots are to be seen.

* Phil. Transf. vol. LXXI. p. 127. and fig. 17.

1781, July 3. 10 h. 54'. *a* seems to be larger than I have seen it, fig. 6.

11 h. 24'. *b* is not yet visible, fig. 7.

12 h. 36'. I perceive part of *b*, fig. 8.

July 4. 12 h. 9'. *a* is very full; *b* extremely thin, and barely visible.

12 h. 18'. *a* and *b* are not quite opposite each other.

12 h. 49'. *b* is increased.

July 15. 9 h. 54'. *a* is visible, fig. 9.

11 h. 35'. *b* invisible.

12 h. 12'. *b* not to be seen.

July 16. 11 h. 9'. The bright spot *a* is very large.

July 17. 11 h. 15'. No other bright spot but *a*.

July 19. 13 h. 31'. *a* visible.

July 20. 10 h. 3'. I suppose the bright spot *a* on Mars is, very nearly, the south pole; which therefore must lie in sight. There is no second bright spot *b* visible to night.

10 h. 56' *b* not visible; the night very fine.

July 22. 11 h. 14'. At *a* and *b*, fig. 10. are bright spots; *a* is larger than *b*. Most probably the south pole is in view, and the north pole just hid from our sight. If the spots are polar, or nearly so, then *a* must, on a supposition of the south pole's being in view, appear larger than *b*; and if *b* extend a little more from the north pole one way than another, it must be subject to some change in its appearance from the revolution of Mars on its axis.

July 30. 9 h. 43'. Both spots visible.

August 8. 10 h. 4'. Only *a* visible, fig. 11.

August 17. 9 h. 21'. Only *a* in sight.

1781, August 23. 8 h. 44'. *a* as usual, and part of *b* visible,
fig. 12.

Sept. 7. The white spot *a* is very large.

1783, May 20. Mars has a singular appearance. At *a*, fig. 13.
is the polar spot, which is bright, and seems to pro-
ject above the disk by its splendour, causing a break
at *c*.

July 4. *a* is very bright.

July 23. 14 h. 45'. *a* is very lucid.

August 16. I saw the bright spot with the 20 feet
reflector as usual.

Aug. 26. The lucid spot on Mars is its south pole, for
it remains in the same place, while the dark equato-
rial spots perform their constant gyrations: it is
nearly circular.

Aug. 29. The south polar spot is in the same situation.

Sept. 9. As usual.

Sept. 22. The south polar spot is of a circular shape,
and very brilliant and white. I had a beautiful and
distinct view of it when it was about the meridian,
and measured its little diameter in the equatorial di-
rection of Mars. With a power of 93² it gave
1' 41'', and I saw it very distinctly. The outward
edge of the spot came just up to the upper limb; a
favourable haze net, taking off every troublesome
ray, gave me objects in general exceedingly well de-
fined, especially Mars.

Sept. 23. 9 h. 55. The polar spot *a*, fig. 14, as usual.

Sept. 24. The same.

1783, Sept. 25. 12 h. 30'. The bright south polar spot *a*, fig.

15. seems to be fixed in its place, and goes nearly up to the margin of the disk; it is perfectly round.

12 h. 55'. The track of the equatorial spots is incurvated, being convex towards the north, see *e*, *q*, fig. 23.: this confirms the white spot's being at the south pole. With long attention I can perceive the edge of the disk of Mars beyond the spot, extending about $\frac{1}{4}$ diameter of the spot.

Sept. 26. 12 h. 10'. The spot *a* is in a line with the center and the end of the hook, fig. 16.

Sept. 27, 28, 29. The spot as usual.

Sept. 30. 10 h. 30'. The polar spot as in fig. 17.

Oct. 1. 9 h. 55'. I am inclined to think, that the white spot has some little revolution, and therefore is not with its center exactly at the pole of Mars; it is rather probable, that the real pole, though within the spot, may lie near the circumference of it, or one-third of its diameter from one of the sides. A few days more will shew it, as I shall now fix my particular attention upon it.

10 h. 17'. The bright spot is certainly not so far upon the disk as it used to be formerly, and is either reduced or has a small motion; which of the two is the case will be seen in a few hours.

13 h. 3'. The bright spot has a little motion; for it is now come farther into the disk.

I concluded now, in general, that none of the bright spots on Mars were exactly at the poles, though they could certainly not be far from them: for what has been just related of the

rst, 2d, and 3d of October 1783, shews plainly, that the appearance of the southern spot *a* was a little affected by the diurnal motion of the planet; and the observations of the 3d and 4th of July 1781, shew also that the spot *b* could not be exactly at the north pole; and that, perhaps, the visible branch of the latter extended pretty far towards the equator. However, the south polar spot of the year 1783, being very small and nearly round, afforded a good opportunity for determining its polar distance, by noting the different angles of position it assumed while Mars revolved on its axis; to this end many observations were taken at different hours of the same night, which will be found among the measures of the angles of position in the next division of my subject. And since the different degrees of brilliancy, as well as the proportional apparent magnitude of the spot, would also contribute to the investigation of this point, I continued my remarks on those particulars, as follows.

1783, Oct. 2. 7 h. 59'. The bright spot near the south pole is about half visible.

Oct. 4. 8 h. 0'. The polar spot seems to project above the disk as formerly, and is very small.

Oct. 5. 11 h. 13'. The spot is very small, and seems actually to be in the circumference.

11 h. 30'. The spot is small, and seems to be with its farthest side in the circumference of the disk; or it may, perhaps, be partly beyond it, and therefore not all in sight.

11 h. 50. I see the spot much clearer than I did before.

13 h. 15'. The white spot is more in sight, and of its usual size, but does not seem much to change its position;

sition; however, what change there is shews that it has been beyond the pole, as it appears to have been direct while the equatorial spots were retrograde.

1783, Oct. 9. 11 h. 48'. The white polar spot increases in size. At 10 h. 35', it was as in fig. 18. but is now larger, and coming round towards that part of its orbit which is nearest to us. See fig. 24.

Oct. 10. 6 h. 20'. I see no white polar spot; but the planet is too low for any observation to be depended on.

6 h. 55'. The white spot begins to be visible; at least I see it now, the planet being higher than before, fig. 19.

9 h. 55'. With 460, the white spot is considerably increased, and shews a circular form, fig. 20.

Oct. 11. 7 h. 46'. The bright spot is very visible; the evening fine; with 278.

Oct. 16. 7 h. 7'. The spot is very luminous.

9 h. 55'. It seems rather lengthened; perhaps it may be arrived at the extreme of its parallel of declination.

Oct. 17. 7 h. 47'. The white spot *a*, fig. 21. is very bright.

13 h. 7'. It is less in appearance than it was in the beginning of the evening.

Oct. 23. 6 h. 46'. The bright spot is very large and luminous; I suppose it to be in the nearer parts of its little orbit.

7 h. 11'. It is situated as in fig. 22.

Oct. 24. 7 h. 1'. The white spot is very large.

Oct. 27. 8 h. 45'. It is very large and round.

Nov. 1. 7 h. 47'. The spot is round and bright.

1783, Nov. 11. The deficiency of light which occasions Mars to appear gibbous, reaches over the south polar spot towards the preceding limb, and hides it.

Nov. 14. Mars is gibbous, and the polar spot is thereby rendered invisible.

Nov. 17. 6 h. 0'. The south polar spot is under the fainter defect of light.

6 h. 30'. I do not know whether there be not a faint glimpse of the polar spot left; the weather is too bad to determine it.

I have added fig. 25. (tab. X.) to shew the connection of the 15th, 17th, 18th, 19th, 20th, 21st, and 22d figures, which complete the whole equatorial circle of appearances on Mars, as they were observed in immediate succession. The center of the circle marked 17 is placed on the circumference of the inner circle, by making its distance from the center of the circle, marked 15, answer to the interval of time between the two observations, properly calculated and reduced to sidereal measure. The same has been done with regard to the circles marked 18, 19, &c. And it will be found, by placing any one of these connected circles, so as to have its contents in a similar situation with the figures in the single representation which bears the same number, that there is a sufficient resemblance between them; but some allowance must undoubtedly be made for the unavoidable distortions occasioned by this kind of projection.

In order to bring these observations on the bright spots into one view, I have placed them at the circumference of three circles (see fig. 26, 27, 28. tab. VII. VIII. IX.) divided into degrees, representing the parallels of declination in which they

revolved about the poles of Mars. The division of the circles marked 360 is where a spot passes that meridian of the planet which is turned towards the earth, and where, consequently, it appears to us in its greatest lustre. The motion of the spot is according to the numbers 30, 60, 90, and so on to 360. In calculating the daily places of the spots I have used the sidereal period of 24 h. 39' 21", 67 determined in my paper on the rotation of Mars*; and have also made proper allowances for the alterations of the geocentric longitudes calculated from the situations of that planet given in the Nautical Almanack; by which means the sidereal is reduced to a proper synodical period.

The following three tables contain the result of the calculations, and serve to explain the arrangement of the observations in the circles. In the first column are the times when the observations were made. In the second, the sidereal places of the spot in degrees and minutes. In the third column are the geocentric longitudes of Mars at the time of the observations. In the fourth, the necessary corrections on account of these different longitudes. In the fifth column are the corrected or synodical places of the spots; and, according to the numbers in that column, they are marked on the circles, where consequently each spot is represented as it must have appeared to be situated at the time of observation.

* Phil. Trans. vol. LXXI. p. 134.

TABLE I.

Time of observation.	Sider. place.	Geoc. longit.	Correction.	Synod. place.
D.	H.	M.	D.	M.
June 23	11 0 36	359 31	9 24 35	35° 31'
25	12 0 15	0 0	9 24 35	0 0
25	13 0 12	13 52	9 24 34	13 51
27	11 0 20	357 28	9 24 12	357 5
28	11 3 15	316 40	9 24 1	316 6
30	10 4 48	290 56	9 23 38	289 59
30	11 0 35	302 23	9 23 38	301 26
July 3	10 5 54	263 40	9 22 55	262 0
3	11 2 24	270 58	9 22 55	269 18
3	12 10	282 9	9 22 55	280 29
3	12 36	288 29	9 22 55	286 48
4	12 9	272 20	9 22 40	279 25
4	12 49	282 4	9 22 40	280 9
15	9 54	134 7	9 19 43	129 15
15	11 35	158 42	9 19 42	153 49
15	12 12	167 42	9 19 42	162 49
16	11 9	142 48	9 19 26	137 39
17	11 15	134 40	9 19 9	129 14
19	13 31	148 37	9 18 34	142 36
20	10 3	88 25	9 18 21	82 11
20	10 56	101 19	9 18 20	95 4
22	11 14	86 32	9 17 49	79 46
30	9 43	347 46	9 16 5	339 16

T A B L E II.

Time of observation.	Sider. place.	Geoc. longit.	Correction.	Synod. place.
D. H. M.	D. M.	S. D. M	D. M.	D. M.
June 25	11 36	86 51	9 24 35	+ 1 40
25	12 15	96 20	9 24 35	+ 1 40
25	13 12	110 12	9 24 34	+ 1 39
28	11 15	53 0	9 24 1	+ 1 6
30	10 48	27 16	9 23 38	+ 0 43
30	11 35	38 43	9 23 38	+ 0 43
July 3	10 54	0 0	9 22 55	+ 0 0
4	12 9	8 40	9 22 40	- 0 15
15	9 54	230 27	9 19 43	- 3 12
15	10 12	234 50	9 19 43	- 3 12
15	11 35	255 2	9 19 42	- 3 13
15	12 12	264 2	9 19 42	- 3 13
16	11 9	339 8	9 19 26	- 3 29
19	13 31	244 57	9 18 34	- 4 21
20	10 3	184 45	9 18 21	- 4 34
20	10 56	197 39	9 18 20	- 4 35
30	9 43	84 6	9 16 5	- 6 50

T A B L E

T A B L E . III.

Time of observation.	Sider. place.	Geoc. longit.	Correction.	Synod. place.
D. H. M.	D. M.	S. D. M.	D. M.	D. M.
Sept. 25	13 30	6 32	0 9 54	+6 44
Oct. 1	10 17	262 5	0 8 6	+4 56
1	13 3	302 29	0 8 5	+4 55
2	7 59	218 55	0 7 50	+4 40
4	8 0	200 0	0 7 15	+4 5
4	8 46	211 12	0 7 15	+4 5
5	11 13	237 23	0 6 55	+3 45
5	11 30	241 31	0 6 55	+3 45
5	11 50	246 23	0 6 55	+3 45
5	13 15	267 4	0 6 54	+3 44
5	14 0	278 1	0 6 53	+3 43
7	8 20	176 8	0 6 23	+3 13
7	10 5	201 41	0 6 22	+3 12
7	11 50	227 14	0 6 21	+3 11
9	11 48	207 35	0 5 49	+2 39
10	6 55	126 42	0 5 37	+2 27
10	7 50	140 5	0 5 36	+2 26
10	9 55	170 30	0 5 34	+2 24
10	12 11	203 36	0 5 33	+2 21
16	7 7	72 9	0 4 15	+1 5
16	7 46	81 39	0 4 15	+1 4
16	9 55	113 2	0 4 14	+1 4
17	7 47	72 19	0 4 3	+0 53
17	13 7	150 11	0 4 0	+0 50
23	6 46	0 0	0 3 10	-0 0
24	7 1	354 0	0 3 2	-0 8
				353 52

From the appearance and disappearance of the bright north polar spot in the year 1781, we collect that the circle of its motion, represented by fig. 26. was at some considerable distance from the pole. By a calculation, made according to the principles hereafter explained, its latitude must have been about 76° or 77° north; for I find that, to the inhabitants of Mars, the declination of the sun, June 25. 12 h. 15' of our time, was about $9^{\circ} 56'$ south*; and the spot must have been at least so

* See p. 259. and 260.

far removed from the north pole as to fall a few degrees within the enlightened part of the disk, to become visible to us.

The south pole of Mars could not be many degrees from the center of the large bright southern spot of the year 1781, whose course is traced in fig. 27; though the spot was of such a magnitude as to cover all the polar regions farther than the 70th or 65th degree, and in that part which was on the meridian July 3, at 10 h. 54', perhaps a little farther.

In the next division of our subject will be shewn, that the inclination and position of the axis of Mars are such, that the whole circle, fig. 28. (which will appear to be in about $81^{\circ} 52'$ of south latitude on the globe of Mars) was in view all the time the observations on the bright south polar spot of the year 1783, which are marked upon it, were made, but in so oblique a situation as to be projected into a very narrow ellipsis. See fig. 24. where *mn* is the little ellipsis in which the spot *a* revolved about the pole. Hence then we may easily account for the observed magnitude and brightness of the spot Oct. 23, 24, and 27. when it was exposed to us in its meridian splendour. Its situations Oct. 16. and 17. on one extreme of the parallel, as well as those of Oct. 5. and Nov. 1. on the other, gave us also a bright view of it: and, when we pass over to that half of the circle which lies beyond the pole, the much greater obliquity into which the spot must there be projected will perfectly account for its being smaller at 13 h. 7' of Oct. 17. than at 7 h. 47' of the same evening. It will also explain its smallness Oct. 4. and its increase Oct. 9. We shall have occasion hereafter to recur to the same figure, so that I take no notice at present of the angles of position which are marked upon it.

Of the direction or nodes of the axis of Mars, its inclination to the ecliptic, and the angle of that planet's equator with its own orbit.

From the foregoing article we may gather, that the bright polar spots on Mars are the most convenient objects for determining the situation of the axis of this planet; I shall therefore collect, in one view, all the measures I have taken of these spots for that purpose. Before I constructed a micrometer for taking the angle of position, I used to draw a line through the figure delineated of Mars to represent the parallel of declination; in a few of my first observations, therefore, I can only take the situation of the polar spots from such drawings, and of consequence no great accuracy in the angles, as to the exact number of degrees, can be expected.

1777, April 17. 7 h. 50'. A line drawn through the middle of the two bright polar spots *a* and *b*, fig. 1. makes an angle of about 63° , with a parallel of declination AB; the southern spot preceding and the northern following.

My reason for chusing a line drawn through both the spots rather than through one of them and the center is, first, that they were not situated quite opposite each other, and therefore, unless other observations had pointed out which was most polar, I should evidently run the greater risk in fixing on one of them in preference to the other. In the next place, we find by the second observation, page 235. that in two hours and a half both spots were intirely gone out of the disk. This plainly

plainly denotes, that they were both in the same half of a sphere orthographically projected, and divided by a plane passing through the axis of Mars and the eye, but that neither of them were polar. Now, a line drawn through two points not far from opposite each other, both in the same hemisphere, and both removed from the poles of it, must approach more to a parallelism with the axis, than a line drawn through either of them and the center.

1779, May 9. There being no bright spots by which to judge of the position of the poles, it is estimated from a well known dark equatorial spot, with a line drawn through the figure to denote a parallel of declination. By very rough estimation it is about 42° south preceding.

May 11. The same figure, being drawn again in another situation, and also with a line giving a parallel of declination, points out, by the same rough estimation, 62° south preceding.

1781, June 25. 11 h. 35'. The position of the spots *a* and *b*, fig. 3. with regard to a parallel of declination, measured with a micrometer $74^{\circ} 32'$. The spot *a* was south preceding, and *b* north following.

July 15. 10 h. 12'. The angle of position, of the center of the spot *a*, fig. 9. through the center of the disk, $74^{\circ} 18'$ south preceding.

1783, August 16. Position of the spot *a*, 64° south following the center; but as the planet is not full, the center becomes dubious, and the measure therefore may not be quite accurate, though taken with a 20 feet reflector; power 200.

1783, Sept. 9. Position of the supposed south pole of Mars
 $65^{\circ} 12'$ south following; 7 feet reflector; power 460.

Sept. 22. Position of the same $52^{\circ} 9'$ s. following; 460.

Sept. 25. 13 h. 30'. Position of the south polar spot
 $56^{\circ} 27'$. very accurately taken, by bisecting the
disk of Mars through the bright spot, and supposing
the planet now near enough the opposition to induce
no material error. Hitherto I have taken it through
a supposed center by endeavouring to allow a little
for what I thought the deficiency in the disk; but
not to-night.

Oct. 4. 8 h. 46'. Position of the spot $51^{\circ} 21'$; Mars
too low and hazy to depend much on the measure
with so high a power as 460.

Oct. 5. The motion of the polar spot being now strongly
suspected, or rather already known, I took the fol-
lowing measures, by way of discovering its quantity.

11 h. 50'. Position very exactly taken $50^{\circ} 6'$ s. fol-
lowing.

14 h. 0'. Position of the spot $49^{\circ} 45'$.

Oct. 7. 8 h. 20'. Position $55^{\circ} 12'$. In order to see how
far this measure might be trusted to, I set $49^{\circ} 36'$ in
the micrometer, which was evidently too small;
next I took $51^{\circ} 36'$, which was also too small; after
this, I took a new measure, and found $55^{\circ} 24'$,
which appeared to me very exact. 10 h. 5'. The
position now was 53° . 11 h. 50'. It measured $52^{\circ} 12'$.
As there is nothing to distinguish the center, it is ex-
tremely difficult to please one's self in bringing the
spot into a line with it.

1783, Oct. 10. 7 h. 50'. Position of the polar spot $57^{\circ} 12'$; with 460, very accurate. I tried a few parts less of the micrometer, but found the measure too little. I see pretty distinctly, but the air is tremulous.

9 h. 55'. Position $52^{\circ} 42'$; very distinct.

12 h. 11'. Position $46^{\circ} 30'$; I see not quite so well now as I could wish.

14 h. 1'. Position $44^{\circ} 12'$; but liable to great uncertainty, on account of tremulous air; it becomes more difficult to distinguish the center when the planet is not perfectly defined.

Oct. 16. 7 h. 7'. Position $63^{\circ} 9'$. By way of trial I set $59^{\circ} 36'$, which was too small; also $60^{\circ} 24'$ was too small; again, $61^{\circ} 24'$ was not large enough. Then, taking a fresh measure, I found it $62^{\circ} 48'$, which I thought right.

9 h. 55'. I took three measures, and thought the third, which was $65^{\circ} 0'$, the best of all, for I saw the planet and the spot remarkably well.

Oct. 27. 8 h. 45'. Position of the polar spot $59^{\circ} 30'$. I took three other measures, of which $60^{\circ} 39'$ appeared to me the best; it was taken with long attention and many changes and trials of the wires in different positions; but the gibbosity of Mars is such, that measures of the situation of the spot are now no longer to be depended on.

These positions, I believe, will be sufficient for the purpose of settling the latitude of the polar spots, and thereby obtaining a correct measure of the situation of the real pole. I have referred those of the south polar spot of the year 1783 to the same circle which contains the observations that were made on

the apparent brightness and magnitude of that spot, that they may be compared together. (See fig. 28.) The agreement of the measures, and the phænomena attending the motion of the spot, are sufficient to point out the meridian of the circle; for which, from a due consideration of these circumstances, I have fixed on the place where the spot was Oct. 10. 6 h. 46'.

Of the angles collected in fig. 28. we find $65^{\circ} 0'$ the largest, and $49^{\circ} 45'$ the smallest; but, on account of the different situation of the earth and Mars, the angle measured 7' less Oct. 16. than it would have done had the planets remained in the places they were in Oct. 5. when the other measure was taken. This being added, we have $65^{\circ} 7'$. The difference between the two positions is $15^{\circ} 22'$. Now, the construction of fig. 28. being admitted, we see that the angles were nearly taken at the opposite extremes of the circle in which the spot moved. However, by the 5th column of Tab. III. Oct. 5. we have the situation of the spot in the circle with respect to the meridian $281^{\circ} 44'$, and Oct. 16. $114^{\circ} 6'$: therefore the south polar distance of the center of the spot is found, by taking half the sum of the sines of these angles to radius, as $7^{\circ} 41'$ (half of $15^{\circ} 22'$) to a fourth number, which is $8^{\circ} 8'$; and the latitude of the circle, in which the spot moved about the pole, therefore is $81^{\circ} 52'$ south. This being determined, we have the following correction for the angles of position: radius is to sine of the angular distance of the spot from the meridian as $8^{\circ} 8'$ to the required quantity. This must be added or subtracted, according as the case requires; and thereby we shall have the position of the true pole from any one of the measures.

I shall now apply the above to determine the situation of the axis of Mars. To this end, we see that, in the first place, the

measures must be corrected for the latitude of the spot; next, they must be reduced to a heliocentric observation, which will also correct them from the difference occasioned by the different situation of the planets when they were taken. This being done, we may select two observations at a proper distance; from which, by trigonometry, we shall have the node and inclination of the axis. When these elements are obtained, it will be easy to see how other observations agree with them; which will afford the means of correcting or verifying the former calculations.

Let T , fig. 29. (tab. X) be the earth; $\odot Q q \wp$ the ecliptic as seen from T ; P the point of the heavens towards which the north pole of the earth is directed; M the place of the orbit of Mars $\mu m M$, where an observation of the poles of that planet has been made, which is to be reduced to its heliocentric measure. And, first, suppose it to have been made at the time of the opposition of that planet. Then, the place M or Q in the ecliptic being given, we have the sides $Q \odot$, $\odot P$; whence the angle Q , of the right-angled triangle $P \odot Q$, is found. This being added to, or taken from, the observed angle of position of the axis of Mars, according to circumstances easily to be determined, reduces it to its heliocentric position. But if this observation was not made at the time of an opposition, but at some other place m , a second correction is to be applied in the following manner.

Let the angle q , of the triangle $P \odot q$, be found as before, and properly applied to the position of the axis of Mars now at m ; then make the angle $m S \mu$, at the sun S , equal to the angle $S m T$, and μ will be the heliocentric place, where the angle of position, when seen from S , will appear to be as it was found at m , after the application of the first correction:

for $S\mu$ being parallel to Tm , and supposing the axis of Mars to preserve its parallelism while it moves from m to μ , appearances of Mars at μ to an eye at S , must be the same as they are at m to an eye at T .

The following table contains the result of calculations relating to the angles of fig. 28. In the first column are the times when the observations were made. In the second, the angles as they were taken. In the third column are the quantities of the angles Q , q , calculated from the geocentric longitudes contained in the third column of the third table. In the fourth column are the corrections for the situation of the spot in the circle of latitude obtained from the sines of the angles in the fifth column of the third table. In the fifth are the corrections requisite on account of the change of situation of the planets, during the interval between the several days on which the measures were taken; these are obtained from the third column of this table, and I have assumed the 4th of October, as being the observation nearest the opposition, to which I have reduced the other measures. In the sixth column are the angles of the second, corrected by the quantities contained in the fourth and fifth columns, applied according to their signs.

T A B L E IV.

Time of observation.			Angles taken.		Angle Q.		First correction.		Second correct.		Angles corrected.	
D.	H.	M.	D.	M.	D.	M.	D.	M.	M.	D.	M.	
Sept. 25	13	30	56	27	+23	10	-1	52	-8	54	27	
Oct. 4	8	46	51	21	+23	18	+4	42	-0	56	3	
5	11	50	50	6	+23	19	+7	39	+1	57	46	
5	14	0	49	45	+23	19	+7	59	+1	57	45	
7	8	20	{ 55 12 } 55 24 }	+23 21	-0	7	+2	{ 55 7 } 55 19				
7	10	5	53 0	+23 21	+3	26	+3	56 29				
7	11	50	52 12	+23 21	+6	16	+3	58 31				
10	7	50	57 12	+23 22	-4	57	+4	52 19				
10	9	55	52 42	+23 22	-1	7	+4	51 39				
16	7	7	{ 63 9 } 62 48 }	+23 25	-7	47	+7	{ 55 29 } 55 8				
16	9	55	65 0	+23 25	-7	23	+7	57 45				

As we have no particular reason to select one measure rather than another, a mean of all the 13 will probably be nearest the truth; so that by these observations, which, as we said before, are reduced to the 4th of October, 1783, we find the position of the axis of Mars that day to have been $55^{\circ} 41'$ south following.

From the appearances of the south polar spot in 1781, represented fig. 27. we may conclude, that its center was nearly polar. We find it continued visible all the time Mars revolved on its axis; and, to present us generally with a pretty equal share of the luminous appearance, a spot which covered from 45° to 60° of a great circle on the globe of Mars could not have any considerable polar distance: however, a small correction in the angle of position seems to be necessary, which should be taken from the measure of the 15th of July, because that branch of the spot which probably extended farthest towards

the

the equator, was then in the *following* quadrant. The measure of both the spots on June the 25th, 1781, is still more to be depended on, as giving us very nearly the position of the true pole; for it appears evident from the phænomena of the bright north-polar spot in fig. 26. that that spot was in the meridian when the measure was taken, while the southern spot was in the *preceding* quadrant near its greatest limit. Now, since an angle at the circumference of a circle is but half the angle at the center, when the arches which subtend these angles are equal, the correction necessary to be applied to the measure taken through the two spots will be but one half of the correction which would have been requisite had it been taken through the center; therefore, in order to reduce this to the condition of the former, we may suppose it to have been taken through the center of Mars when the spot was only 30, or 150 degrees from the meridian. It is also necessary to add 1° 54' to the angle of July 15, which it would have measured more had the planets remained where they were June 25. This done, we may have the polar distance of the center of the spot as before. Half the sum of the sines (of 231° 38' and 150°) to radius, as 50' (half the difference between 74° 32' and 76° 12') to a fourth number, which is 1° 18'.

I should observe here, that the measures of the angle of position would be too large before the spot came to the meridian, and too small afterwards, the axis of Mars being south preceding; whereas, in fig. 28. they would be too small before, and too large after, the meridian passage, the pole being south following.

These two observations arranged as those in the fourth table, and reduced to the time of the 25th of June, will stand as follows.

T A B L E V.

Time of observation.	Angles taken.	Angle Q.	First correction.	Second correct.	Corrected Angle.
D. H. M.	D. M.	D. M.		D. M.	D. M.
June 25 11 36	74 32	- 10 14	+ { half of 1° 18'	- 0 0	75 11
July 15 10 12	74 18	- 8 20	- 1 1	+ 1 54	75 11

I am to remark, that we have here admitted both measures as equally good; and that, therefore, the result is a mean of them both, and shews the axis of Mars, June 25, 1781, to have been $75^{\circ} 11'$ south preceding.

Our next business will be to reduce these two geocentric observations to a heliocentric measure. This is to be done, as we have shewn before, by a calculation of the angle Q, fig. 29. The result of it shews, that $10^{\circ} 14'$ are to be subtracted from the mean corrected angle of position, reduced to June 25, 1781, and $23^{\circ} 18'$ to be added to the angle which is the corrected mean of 13 measures, reduced to Oct. 4, 1783. Hence we learn, that on those days and hours, when the heliocentric places of Mars were 9 s. $24^{\circ} 35'$, and 0 s. $7^{\circ} 15'$ (which would happen about July 18, 1781, and Sept. 29, 1783) an observer placed in the sun would have seen, on the former, the axis of Mars inclined to the ecliptic $64^{\circ} 57'$, the north pole being towards the left; and on the latter, he would have seen the same axis inclined to the ecliptic $78^{\circ} 59'$, the north pole being then towards the right.

The first conclusion we may draw from these principles is, that the north pole of Mars must be directed towards some point of the heavens between 9 s. $24^{\circ} 35'$ and 0 s. $7^{\circ} 15'$; because the change of the situation of the pole from left to right, which

which happened in the time the planet passed from one place to the other, is a plain indication of its having gone through the node of the axis. Next, we may also conclude, that the node must be considerably nearer the latter point of the ecliptic than the former; for, whatever be the inclination of the axis, it will be seen under equal angles at equal distances from the node.

But, by a trigonometrical process of solving a few triangles, we soon discover both the inclination of the axis, and the place where it intersects the ecliptic at rectangles (which, for want of a better term, I have perhaps improperly called its node). Accordingly I find, by calculation, that the node is in $17^{\circ} 47'$ of Pisces, the north pole of Mars being directed towards that part of the heavens; and that the inclination of the axis to the ecliptic is $59^{\circ} 42'$.

We shall now compare the observations of an earlier date with these principles, to see how far they agree. Some of the particulars and calculations relating to them are as follow.

T A B L E VI.

Times of Observation.	Estimations.			Geoc. longit.			Angle Q.	2d correct.
D. H. M.	D.	S.	D.	M.	D.	M.		
1779, May 9 12 0	42	7	22	20	+14	45	+	0
May 11 12 0	62	7	21	40	+15	11	+	26
1777, Apr. 17 7 50	63	6	3	34	+23	26		

May the 9th, 1779, as we have seen, the angle of position was roughly estimated at 42° , and May 11. at 62° . The great disagreement of these coarse estimations is undoubtedly owing to the very different situation of the dark spot from which they

were taken; however, since we do not mean to use these observations in our calculations, they may suffice in a general way to shew, that the axis of Mars was actually about that time in such a situation as our principles give it: for, reducing the two positions to the 9th of May, that of the 11th, from an allowance of $26'$ for the situation of the planets, will become $62^\circ 26'$; and a mean of the two, $50^\circ 13'$ south preceding; which, reduced to a heliocentric observation, gives $66^\circ 30'$, the north pole lying towards the left. Now, on calculating from the position of the node and inclination of the axis before determined, we find, that the heliocentric angle was $62^\circ 49'$, the north pole pointing towards the left; and a nearer agreement with these principles could hardly be expected from estimations so coarse. If we go to the year 1777, and take the position of the two bright spots observed the 17th of April, we have 63° south preceding; this, reduced to a heliocentric quantity, gives $86^\circ 26'$ of inclination, the north pole being to the left. By calculating we find, that that pole was then actually $81^\circ 27'$ inclined to the ecliptic, and pointed towards the left as seen from the sun.

The inclination and situation of the node of the axis of Mars, with respect to the ecliptic being found may thus be reduced to that planet's own orbit. Let EC, fig. 30. (tab. X.) be a part of the ecliptic; OM part of the orbit of Mars; PEO a line drawn from P, the celestial pole of Mars, through E, that point which has been determined to be the place of the node of the axis of Mars in the ecliptic, and continued to O where it intersects the orbit of Mars. Now, if according to Mr. DE LA LANDE we put the node of the orbit of Mars for 1783, in 1 s. $17^\circ 58'$, we have from the place of the node of the axis (that is, 11 s. $17^\circ 47'$) to the place of the node of the orbit,

an arch EN of $60^\circ 11'$; in the triangle NEO, right-angled at E, there is also given the angle ENO, according to the same author, $1^\circ 51'$, which is the inclination of the orbit of Mars to the ecliptic. Hence we find the angle EON $89^\circ 5'$, and side ON $60^\circ 12'$. Again, when Mars is in the node of its orbit N, we have, by calculation from our principles, the angle PNE = $63^\circ 7'$, to which, adding the angle ENO = $1^\circ 51'$, we have PNO = $64^\circ 58'$; from which two angles PON and PNO with the distance ON, we obtain the inclination of the axis of Mars, and place of its node with respect to that planet's own orbit; the inclination being $61^\circ 18'$, and the place of the node of the axis $58^\circ 31'$ preceding the intersection of the ecliptic with the orbit of Mars, or in our $19^\circ 28'$ of Pisces.

Being thus acquainted with what the inhabitants of Mars will call the obliquity of their ecliptic, and the situation of their equinoctial and solstitial points, we are furnished with the means of calculating the seasons on Mars; and may account, in a manner which I think highly probable, for the remarkable appearances about its polar regions.

But first it may not be improper to give an instance how to resolve any query concerning the martial seasons. Thus, let it be required to compute the declination of the Sun on Mars, June 25, 1781, at midnight of our time. If $\nu\alpha\pi\odot$, &c. fig. 31. (tab. X.) represent the ecliptic of Mars, and $\nu\odot\pi\nu$ the ecliptic of our planet, Aa, bB, the mutual intersection of the martial and terrestrial ecliptics, then there is given the heliocentric longitude of Mars, $\nu m = 9 s. 10^\circ 30'$; then taking away six signs, and $\simeq b$, or $\nu a = 1 s. 17^\circ 58'$, there remains $b m = 1 s. 22^\circ 32'$. From this arch, with the given inclination, $1^\circ 51'$, of the orbits to each other, we have cosine of inclination to radius, as tangent of $b m$ to tangent of BM = $1 s. 22^\circ 33'$. And

taking away $B\gamma = 1\text{ s. }1^\circ 29'$, which is the complement to ϖB (or $\odot A$, already shewn to be $1\text{ s. }28^\circ 31'$) there will remain $\gamma M = 0\text{ s. }21^\circ 4'$, the place of Mars in its own orbit *; that is, on the time abovementioned, the sun's longitude on Mars will be $6\text{ s. }21^\circ 4'$, and the obliquity of the martial ecliptic $28^\circ 42'$ being also given, we find, by the usual method, the sun's declination $9^\circ 56'$ south.

The analogy between Mars and the earth is, perhaps, by far the greatest in the whole solar system. Their diurnal motion is nearly the same; the obliquity of their respective ecliptics, on which the seasons depend, not very different; of all the superior planets the distance of Mars from the sun is by far the nearest alike to that of the earth: nor will the length of the martial year appear very different from that which we enjoy, when compared to the surprising duration of the years of Jupiter, Saturn, and the Georgium Sidus. If, then, we find that the globe we inhabit has its polar regions frozen and covered with mountains of ice and snow, that only partly melt when alternately exposed to the sun, I may well be permitted to surmise that the same causes may probably have the same effect on the globe of Mars; that the bright polar spots are owing to the vivid reflection of light from frozen regions; and that the reduction of those spots is to be ascribed to their being exposed to the sun. In the year 1781, the south polar spot was extremely large, which we might well expect, since that pole had but lately been involved in a whole twelve-month's darkness and absence of the sun; but in 1783 I found it considerably smaller than before, and it decreased continually

* If no very great accuracy be required, we may add $3\text{ s. }10^\circ 34'$ to any given place of our ecliptic, which will at once reduce it to what it should be called on the orbit of Mars, and will always be true to within a minute.

from the 20th of May till about the middle of September, when it seemed to be at a stand. During this last period the south-pole had already been above eight months enjoying the benefit of summer, and still continued to receive the sun-beams; though, towards the latter end, in such an oblique direction as to be but little benefited by them. On the other hand, in the year 1781, the north polar spot, which had then been its twelve-month in the sun-shine, and was but lately returning to darkness, appeared small, though undoubtedly increasing in size. Its not being visible in the year 1783 is no objection to these phænomena, being owing to the position of the axis, by which it was removed out of sight; most probably, in the next opposition we shall see it renewed, and of considerable extent and brightness; as, by the position of the axis of Mars, the sun's southern declination will then be no more than $6^{\circ}25'$ on that planet.

Of the spheroidal figure of Mars.

That a planetary globe, such as Mars, turning on an axis, should be of a spheroidal form, will easily find admittance, when two familiar instances in Jupiter and the earth, as well as the known laws of gravitation and centrifugal force of rotatory bodies, lead the way to the reception of such doctrines. So far from creating difficulties or doubts, it will rather appear singular, that the spheroidal form of this planet, which the following observations will establish, has not already been noticed by former astronomers; and yet, reflecting on the general appearances of Mars, we soon find that opportunities for making observations on its real form cannot be very frequent: for, when it is near enough to view it to an advantage, we see it

generally gibbous, and its oppositions are so scarce, and of so short a duration, that in more than two years time we have not above three or four weeks for such observations. Besides, astronomers being already used to see this planet generally distorted, the spheroidal form might easily be overlooked.

Observations relating to the polar flattening of Mars.

1783, Sept 25. 9 h. 50'. I can plainly see that the equatorial diameter of Mars is longer than the polar. Measure of the equatorial diameter $21''\ 53'''$; of the polar diameter $21''\ 15'''$ *full measure*, that is, certainly not too small. The wires were set as outward tangents to the disk, and the zero, as well as the measures, were taken by the light of Mars.

Sept. 28. 14 h. 25'. I shewed the difference of the polar and equatorial diameters of Mars to Mr. WILSON, Assistant Professor of Astronomy at Glasgow. He saw it perfectly well, so as to be entirely convinced it was not owing to any defect or distortion occasioned by the eye lens; and, because I wished him to be satisfied of the reality of the appearance, while he was observing, I reminded him of several well known precautions; such as causing the planet to pass directly through the center of the field of view, and judging of its figure at the time when it was most distinct and best defined, and so forth.

Sept. 29. I shewed the difference of the polar and equatorial diameters of Mars to Dr. BLAGDEN and Mr. AUBERT. Dr. BLAGDEN not only saw it immediately,

dately, but thought the flattening almost as much as that of Jupiter. Mr. AUBERT also saw it very plainly, so as to entertain no manner of doubt about the appearance.

As we cannot take too many opportunities of confirming our own observations by the eyes of other observers, I esteemed it a very fortunate circumstance to have the honour of a visit from these gentlemen at so particular a time, Mars being this day within 37 hours of the opposition, and yesterday when Mr. WILSON saw it, within about two days and a half.

1783, Sept. 30. 10 h. 52'. The difference in the diameters of Mars is very evident and considerable.

Measure of the equatorial diameter 22" 9"" with 278.

Second measure - - - 22" 31"" full large.

Polar diameter very exact - - 21" 26"".

Oct. 1. 10 h. 50'. I took measures of the diameters of Mars with my 20-feet reflector. The equatorial measured 103 parts of the micrometer; the polar 98. The value of the divisions in seconds and thirds not being well determined, on account of some late change in the focal length of the several 20-feet object metals I use, we have only from these measures the proportion of the diameters as 103 to 98.

13 h. 15'. Every circumstance being favourable, I took the following measures of the diameters of Mars with my 7-feet reflector, and a distinct power of 625.

Equatorial diameter 22" 12" narrow measure.

22" 46" rather full.

22" 35" exact.

Polar

Polar diameter $21''\ 24'''$

$21''\ 33'''$ very exact.

I saw Mars perfectly well all the time I measured, with all its figures upon the disk appearing distinctly; and, I think, these measures may be depended upon better than any I have yet taken.

1783, Oct 5. 14 h. 0'. The difference of the diameters is very sensible.

Oct. 7. 9 h. 43'. The flattening of the poles is very visible.

13 h. 40'. I turned my Newtonian 7-feet reflector one quarter round, so as to bring the place to look in at to the bottom; and, as well as the uneasy posture would allow, I saw the flattening of the poles the same as when I looked in at the side; power 460.

14 h. 30'. With a $3\frac{1}{2}$ feet achromatic telescope and a single eye lens, I saw the difference of the polar and equatorial diameters very plainly.

Oct. 9. 8 h. 40'. I turned my reflector 90° round, so as now to look in at the upper end, but saw not the least difference in appearances; for, returning it again immediately to its usual position, in both cases the equatorial diameter appeared a little longer than the other; power 278, and the evening fine.

I turned the great speculum one quadrant in its cell, but appearances were not in the least altered; the equatorial diameter still was a little longer than the polar one.

I tried a very fine new object speculum, and found also the equatorial diameter a little longer than the polar one.

1783, Oct. 9. 10 h. 47'. The flattening at the poles very visible.

Oct. 10. 9 h. 55'. A little of the polar flattening is visible, so as to admit of no doubt; power 460, very distinct.

11 h. 32'. Mars visibly flattened, but not much; the achromatic shews it also.

11 h. 42'. The disk of Mars is visibly spheroidal.

Oct. 11. 7 h. 37'. Mars is plainly gibbous, therefore measures and estimations of the diameters must for the future be improper.

11 h. 12'. It is rather difficult to say of what shape Mars is now, for it is partly flattened and partly gibbous; but the gibbous side not being quite in the polar direction of Mars, this produces altogether an odd mixture of shapes: however, upon the whole, the polar diameter is still rather the smallest.

11 h. 13'. The *preceding* side of Mars shews the flattening of the poles, while the *following* is terminated by an elliptical arch.

Oct. 12. 11 h. 12'. The flattening upon the whole is visible.

Oct. 17. 13 h. 7'. The effect of gibbosity is scarcely equal to the flattening; or, upon the whole, the planet is still rather broader over the equator than over the poles.

Nov. 1. 7 h. 56'. The semi-disk, which is *full*, is evidently part of an oblate spheroid; but, to an eye not attentively looking for it, and knowing the shape and exact situation of the poles of Mars, this would probably not appear.

1783, Nov. 10. 9 h. 30'. The gibbosity of Mars is now such, that the polar diameter is considerably longer than the equatorial; but the deficiency not being exactly from pole to pole, makes the disk of a crooked, irregular figure, and renders precision in this estimation impossible; otherwise the phase of Mars would have made a pretty good micrometer upon the equatorial diameter, and it was with such a view I had directed my attention to this circumstance: appearances, however, are visibly in favour of the polar diameter's being the longest.

We find that the quick alterations in the visible disk of Mars, during the time it is in the best situation for us to observe it, are such, that if we were to use many measures which have been taken of its diameters, we should be obliged to have recourse to a computation of its phases, in order to make proper allowance for them. Now, since these changes are in a longitudinal direction, and the poles of Mars are not perpendicular to the ecliptic, it would bring on a calculation of small quantities, which it is always best not to run into where it can be avoided. For this reason, I shall at once settle the proportion of the equatorial to the polar diameter of this planet, from the measures which were taken on the very day of the opposition. I prefer them also on another account, which is, that they were made in a very fine, clear air, and were repeated with a very high power, and with two different instruments, of whose faithful representation of celestial objects, the many observations on very close double stars I have made with them have given me very evident proofs.

As we are at present only in quest of the proportion of one diameter to the other, the measures of the 20-feet reflector, though not given in angular quantities, will equally suffice for the purpose. By them we have the equatorial diameter to the polar as 103 to 98, or as 1355 to 1289. I have turned the proportion into the latter numbers by way of comparing them the better with the measures of the 7-feet reflector. By that instrument the equator of Mars, Oct. 1. we find, was measured three times; but from the remarks annexed to the different results, I think the third measure should be used. Indeed, on taking the difference of the two first, which is 34'', and dividing by three, we have the quotient $11\frac{1}{3}''$; then, allotting two-thirds to the first, because the remark says positively "narrow measure," it becomes $22''\ 34\frac{2}{3}''$, and taking one-third from the second, which is expressed doubtfully, "rather too full," it becomes $22''\ 35\frac{1}{3}''$: this reflection on the two first measures gives additional validity to the third, which is $22''\ 35''$, or $1355''$. The polar diameter was measured twice; and as no reason appears against either of the observations, I shall take the mean of both, which is $21''\ 29''$, or $1289''$; so that by these measures the equatorial diameter of Mars is to the polar as 1355 to 1289. A less perfect agreement between the proportions of the diameters arising from the measures of the 20-feet reflector and those which we have just now deduced from the 7-feet, would have been sufficient for our purpose, as we might easily have excused one or two thousandths of the whole quantity; however, we have no cause to be displeased with this coincidence, though it should in part be owing to accident, and therefore shall admit the above proportion, and proceed to a farther examination of it.

In the first place, it will be necessary to see whether any correction be required on account of the different heliocentric and geocentric south latitude of Mars; which would apparently compress the polar diameter a little, by the defect of illumination on the north. On computation we find, that a difference arising from that cause would give the longitudinal diameter to the latitudinal as 20000 to 19987; which being much less than one thousandth part of the whole, may therefore be neglected.

But next, a very considerable correction must be admitted, when we take into account the position of the axis of Mars. The declination of the sun on that planet, at the time the measures were taken, was not less than 27° south; so that the poles were not in the circumference of the disk by all that quantity. On a supposition then, that the figure of Mars is an elliptical spheroid, we are now to find the real quantity of the polar diameter from the apparent one. It has been proved, that, in the ellipsis, the excesses of any diameters above the polar one are as the squares of the cosines of the latitudes*; but the diameter at rectangles to the equator of Mars, which was exposed to our view in the late opposition, was not the polar one, but such as must take place in a latitude of 63° . Putting therefore $m = \cosine\ of\ 63^{\circ}$, $a = 1355$, $b = 1289$, $x =$ the polar axis, we have $1 : m^2 :: a - x : b - x$. And $\frac{b - m^2 a}{1 - m^2} = x$; which gives us 1272 nearly, for the polar diameter. The true proportion, therefore, of the equatorial to the polar diameter will be as 1355 to 1272; which, reduced to smaller but less accurate numbers, is 16 to 15 nearly.

* Astr. par M. DE LA LANDE, § 2680.

I shall

I shall now also mention some of the other measures, but with a view only to shew that they are very consistent with the above determination. From those of the 30th of September, for instance, we collect the proportion of the diameters of Mars as 1340 to 1286; or, reduced to our former numbers, 1355 to 1300. Now, since these measures were taken the night before the opposition, they must on that account be as good as the former; and, had those of the day of opposition not been preferred, because they were oftener repeated, and the superior power of the 7, and great light of the 20-feet reflector, gave them additional weight, I should have taken them into the account; the very small difference, however, cannot but strengthen the results of the former measures.

From the observations of the 25th of September we have the proportion of the diameters as 1313 to 1275; and if the equatorial measure be increased in the ratio of 20000 to 19953, on account of the different heliocentric and geocentric longitude, Mars not being at the full, it will give the ratio of 1316 to 1275; or, conforming to our former numbers, as 1355 to 1312. I have not been very strict in the application of the correction deduced from the phases of Mars, since no other use was intended to be made of these numbers than merely to shew, that they do not very greatly differ from those we have assigned before *.

It

* If more strictness be required, let EC, fig. 32. be the ecliptic; PS its poles; p the poles of Mars, and eq its equator. Then, the angle pmC being found, by calculation, we shall have Cm (radius) to cm (cosine of the difference between the heliocentric and geocentric longitude) as qv (sine of the angle qmv or pmC) to av . Then, since with Mars Cc can never be very great, the small triangle qno may be taken for similar to qvq ; therefore qm (radius) is to qv (sine of pmC)

It was observed, Oct. 17, 1783, that the equatorial diameter of Mars was still greater than the polar, notwithstanding the depredation of the defect of light upon it. On calculating the phases, we find, that the longitudinal diameter was, that day, to the latitudinal one as 19711 to 20000, which therefore could not be an equal balance to oppose the spheroidal figure so as to render it invisible.

But, Nov. 10. the proportion of the longitudinal diameter to the latitudinal one, from a computation of the phase of Mars, must have been as 18762 to 20000; and accordingly it was by observation found to be more than sufficient to take off all appearance of the polar flattening, and leave a visible excess in the axis above the equator.

To obviate any doubts concerning a fallacy that might arise from the convexity of the eye-glaſs, or irregular shape of the small speculum, I need only refer, for the latter, to the experiments of the 7th and 9th of October, 1783: for should the short diameter of my small plane speculum have occasioned a compressing of the polar diameter of Mars when exposed to it, half a turn of the telescope must bring the other diameter of that speculum into the same situation, and a contrary effect would have followed. With regard to the former, not only the experiments made with the achromatic, but principally the observation with the 20-feet reflector, where I used a compound eye-piece magnifying only about 300 times, will sufficiently exculpate the eye-glasses. It is also well known, that in a single lens the distortion of the images, if any such there

ϕmC) as qo ($=qv-v_o$) to qn ; which is the required correction or deficiency of the equatorial diameter eq of Mars.

Or, putting $mC=1$ and $vq=m=\cosine$ of the angle Pmp ; it will be $qn=m^2 \cdot eC$.

should be, will equally affect the wires of the micrometer, and give a true measure notwithstanding; and the compound eye-piece I used with the 20-feet reflector had likewise the same advantage, for it is constructed on the plan lately proposed by Mr. RAMSDEN in the Philosophical Transactions*, which he was so obliging as to communicate to me about a twelve-month ago, and which I immediately adapted to my large micrometers.

On the subject of the figure of Mars I ought to remark also, that perhaps the measures which were taken of its diameters during the last opposition will enable us to ascertain its real size with greater accuracy than has been done before. The micrometer which can distinguish with precision between the equatorial and polar diameters of this small planet, will certainly be admitted as an evidence of considerable consequence; and since the result of these measures is pretty different from what former observations give us, I should not omit mentioning it.

We have seen that the equatorial diameter, on the day of the opposition, measured $22''\ 35''$. The distance of Mars from the earth at that time was .40457, the mean distance of the earth from the sun being 1; therefore, $22''\ 35''$ reduced to the same distance will be no more than $9''\ 8''$.

I shall conclude this subject with a consideration relating to the atmosphere of Mars. Dr. SMITH † reports an observation of CASSINI's, where "a star in the water of Aquarius, at the distance of six minutes from the disk of Mars, became so faint before its occultation, that it could not be seen by the naked eye, nor with a 3-feet telescope." It is not men-

* Vol. LXXIII. p. 94.

† Optics, § 1096.

tioned!

tioned what was the magnitude of the star; but, from the circumstance of its becoming invisible to the naked eye, we may conclude, that it must have been of the sixth or seventh magnitude at least. The result of this observation would indicate an atmosphere of such an extraordinary extent, since at the distance of 36 semi-diameters of the planet it should still be dense enough to render so considerable a star invisible, that it will certainly not be amiss to give an observation or two which seem of a very different import.

1783, Oct 26. There are two small fixed stars preceding Mars, of different sizes; with 460 they appear both dusky red, and are pretty unequal; with 278 they appear considerably unequal. The distance from Mars of the nearest, which is also the largest, with 227 measured $3' 26'' 20'''$. Some time after, the same evening, the distance was $3' 8'' 55'''$, Mars being retrograde. I saw them both very distinctly. I viewed the two stars with a new 20-feet reflector of 18,7 inches aperture, and found them, as I expected, very bright.

Oct. 27. I see the two small stars again. The small one is not quite so bright in proportion to the large one as it was last night, being a good deal nearer to Mars, which is now on the side of the small star; but when I draw the planet aside, or out of view, I see it then as well as I did last night. The distance of the small star measured $2' 56'' 25'''$ *.

* The measures were accurate enough for the purpose, though not otherwise to be depended on nearer than, perhaps, six or eight seconds.

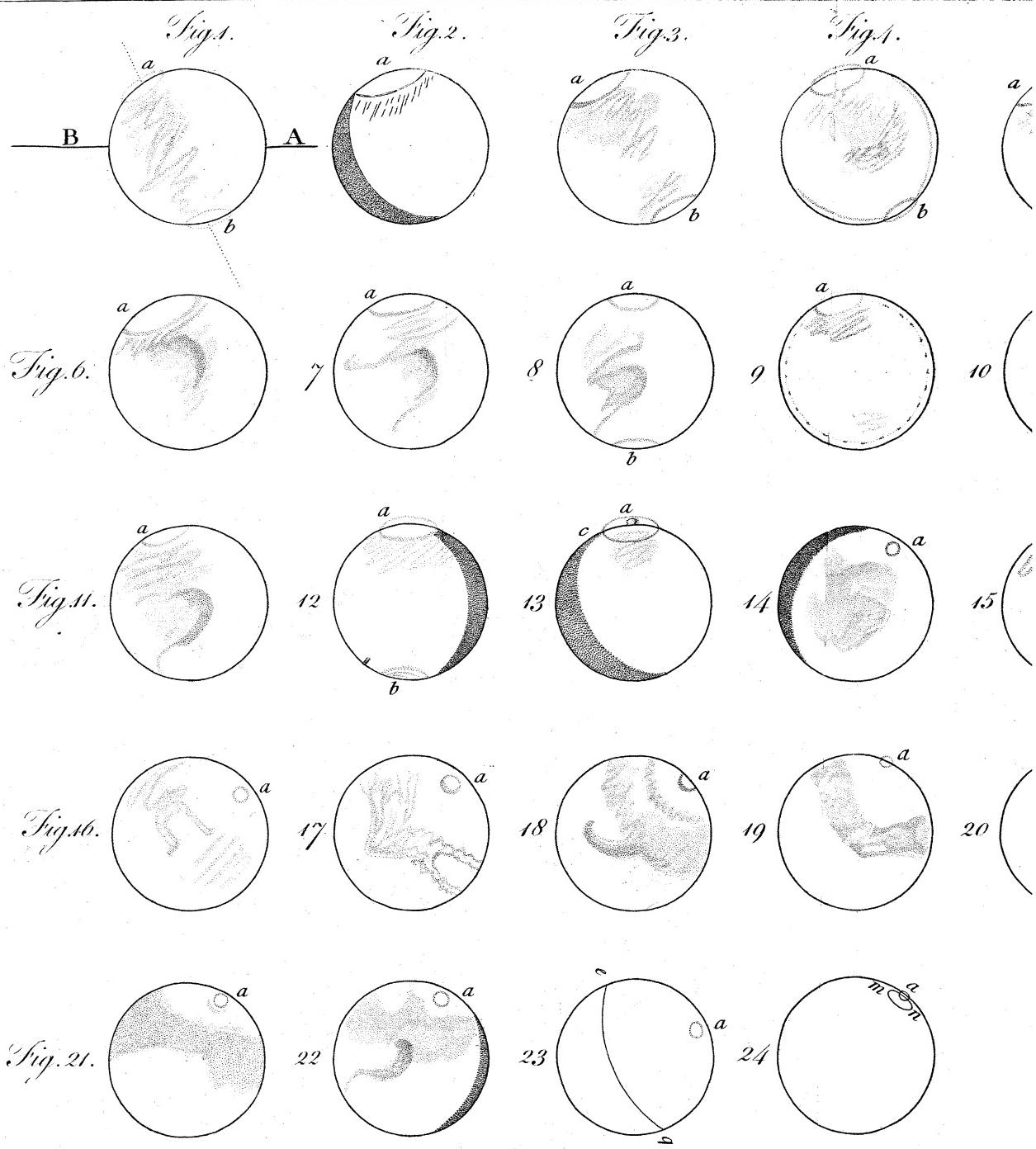
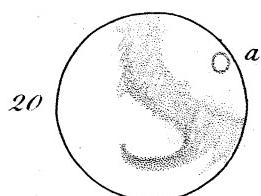
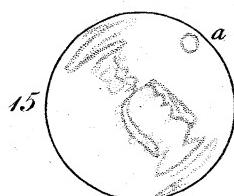
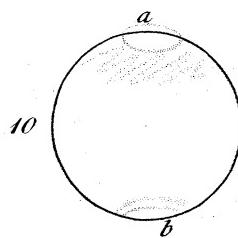
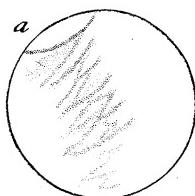
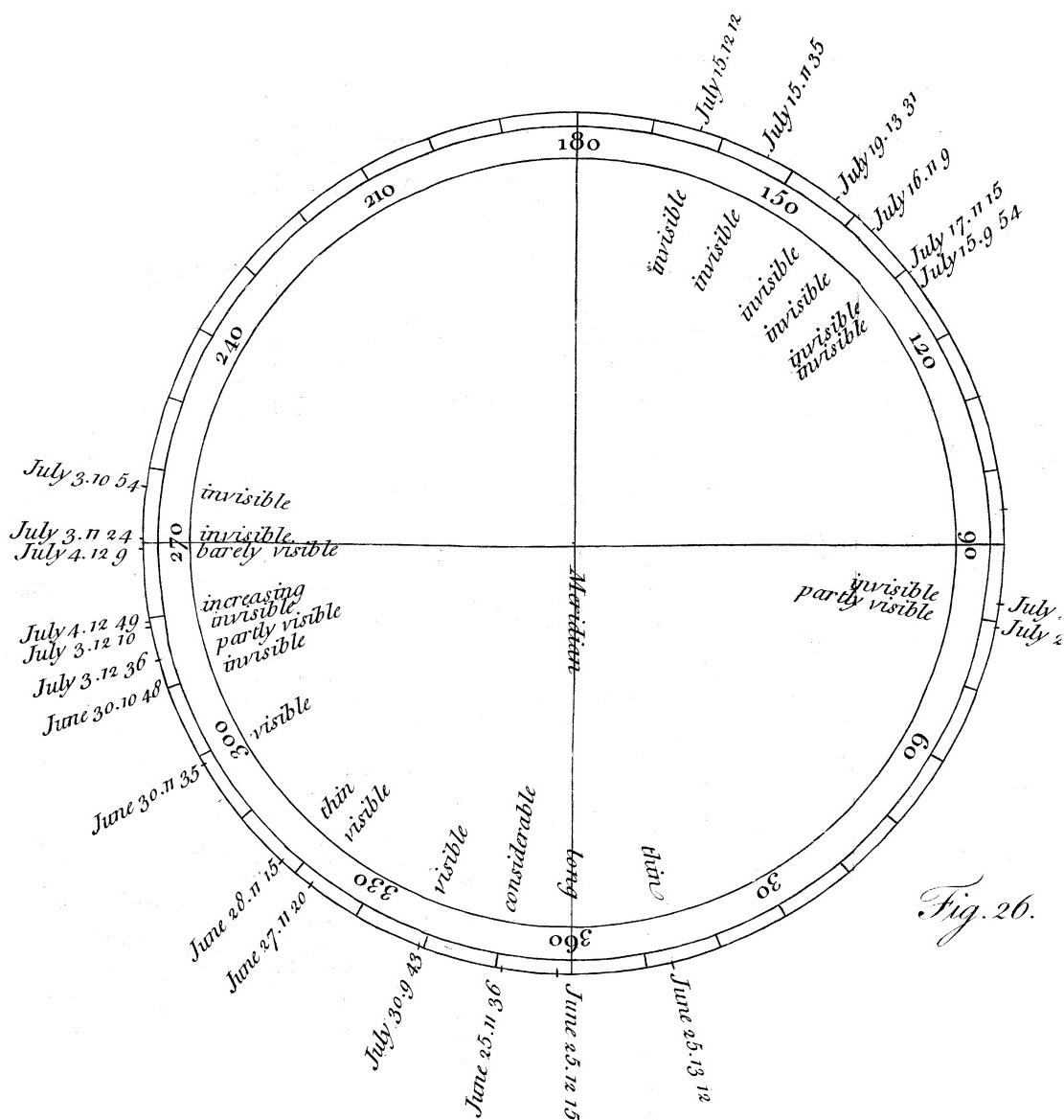
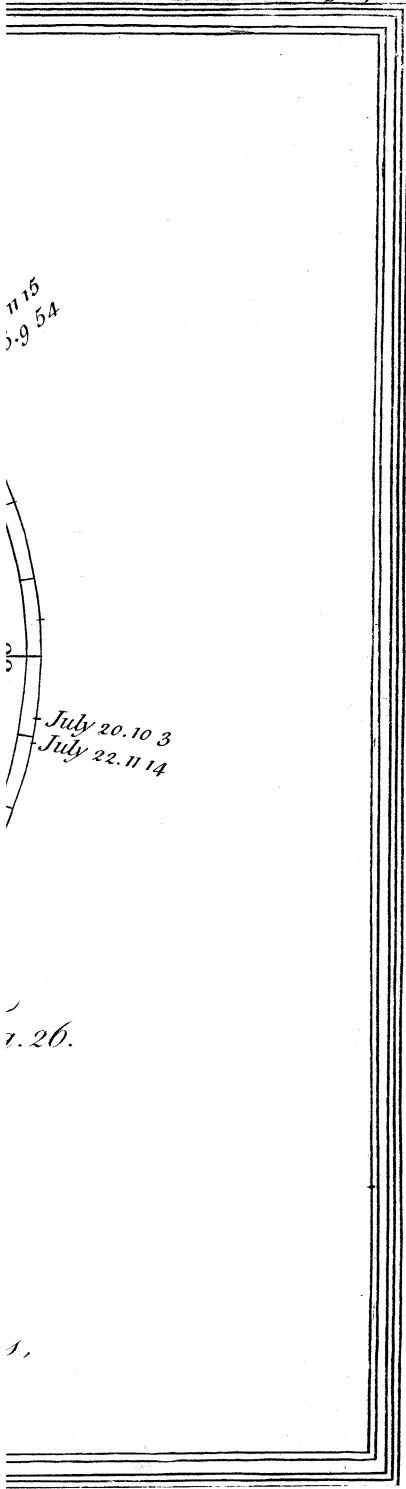


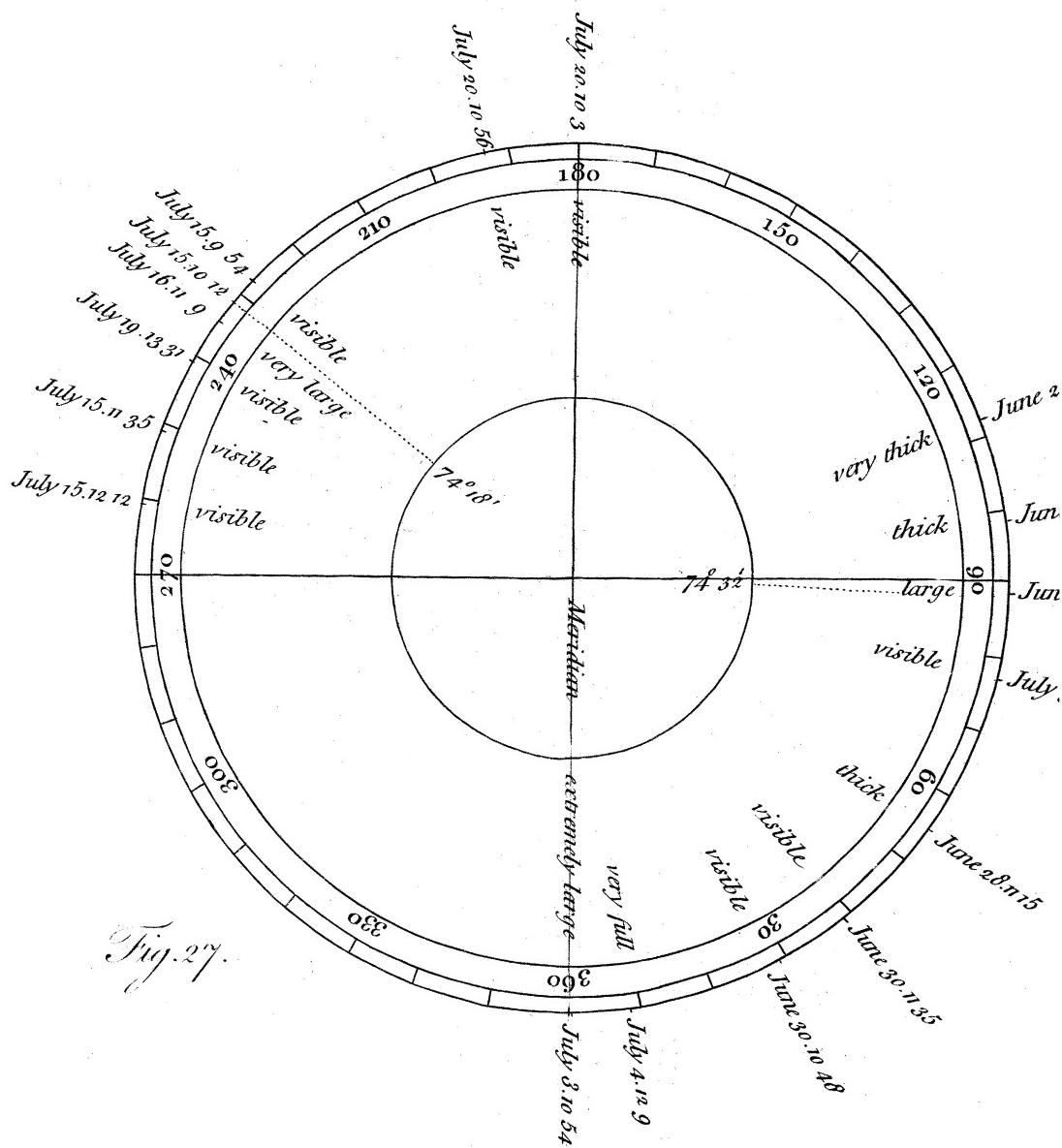
Fig. 5.



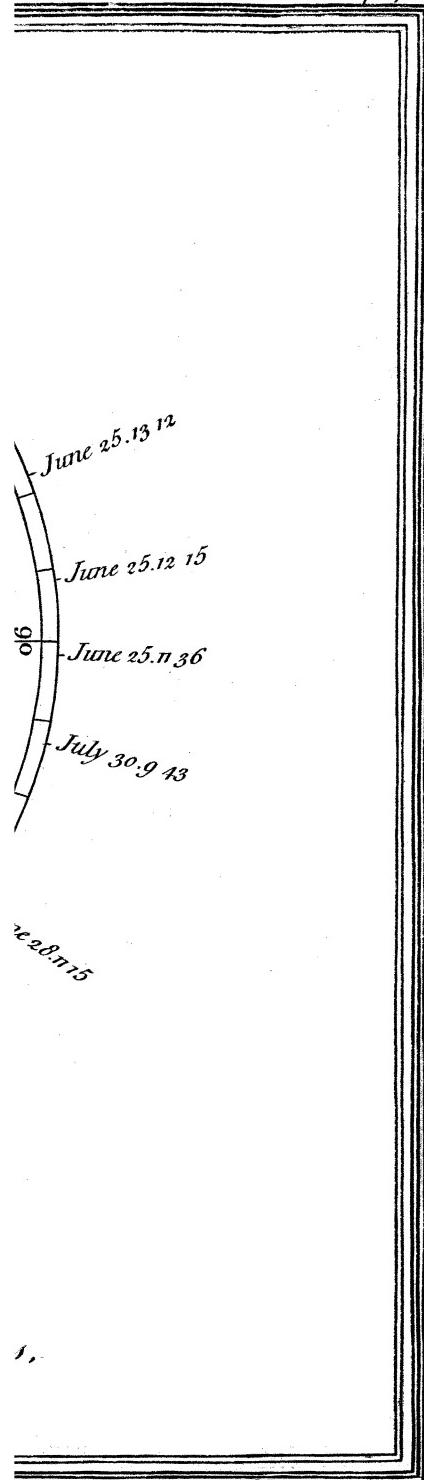


*Track of the bright north polar spot on Mars,
in June & July 1781.*





Track of the bright south polar spot on Mars,
in June & July 1781.



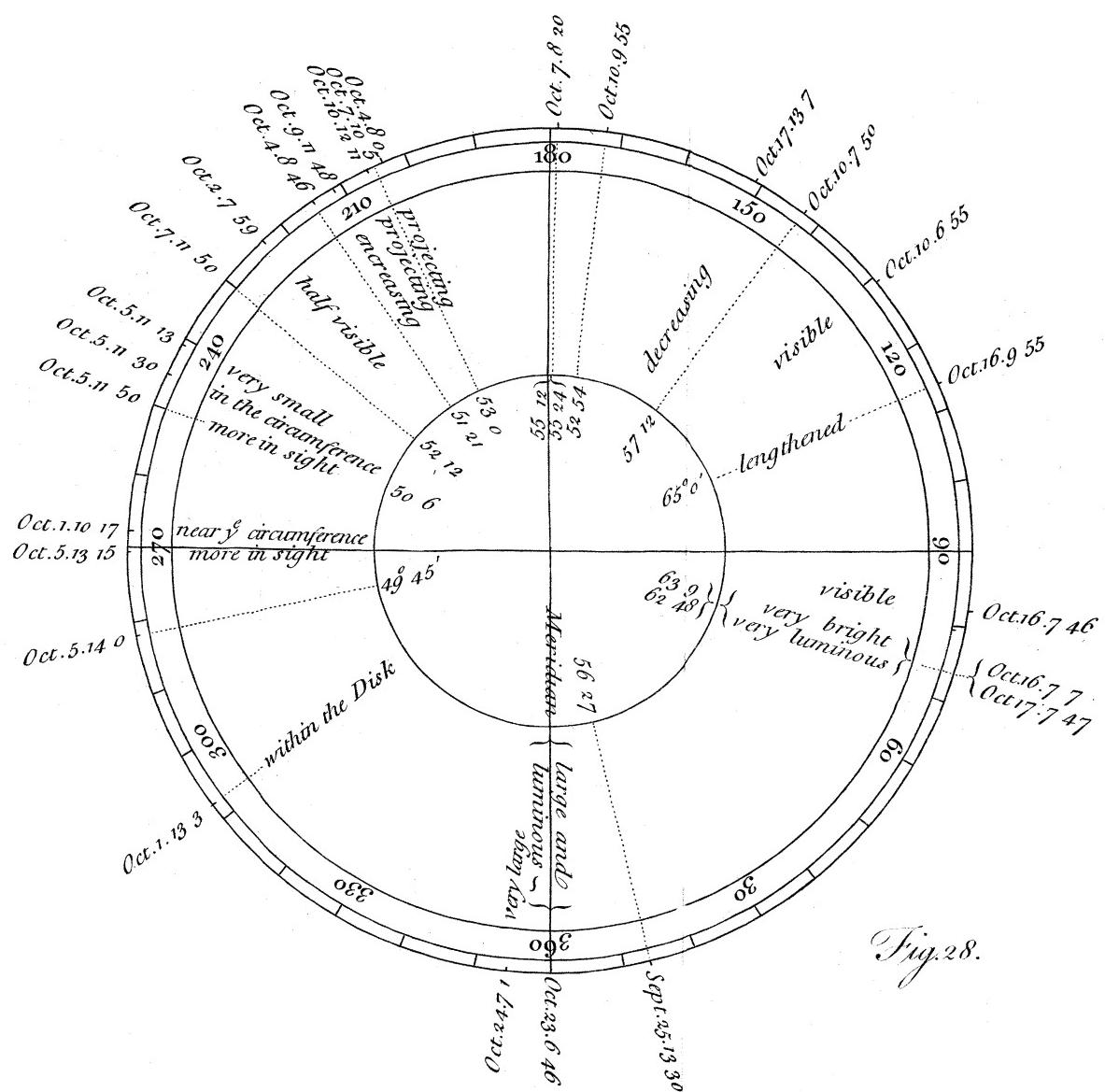
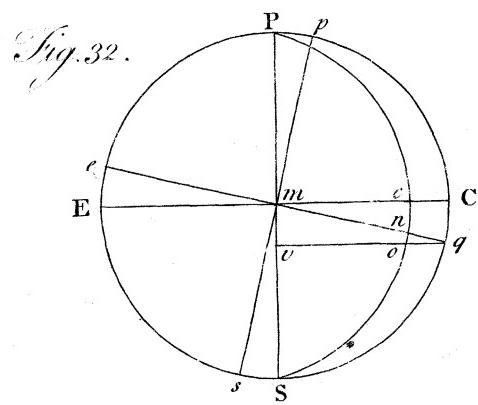
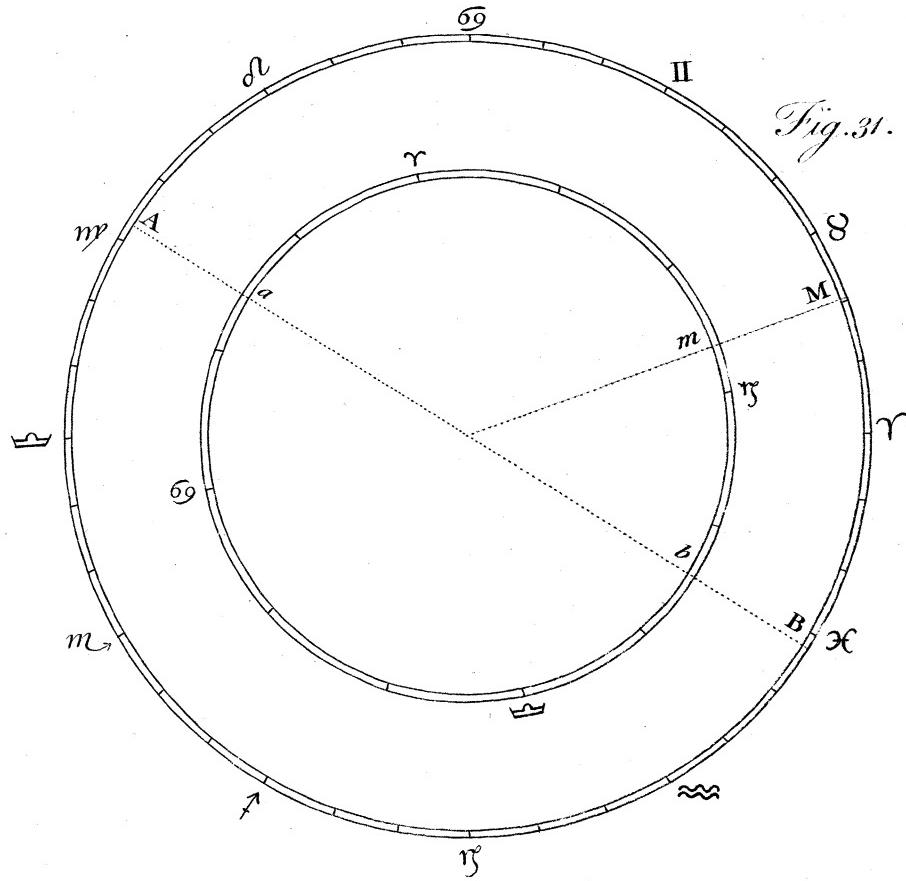
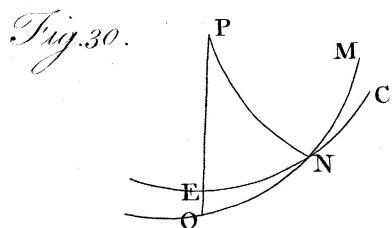
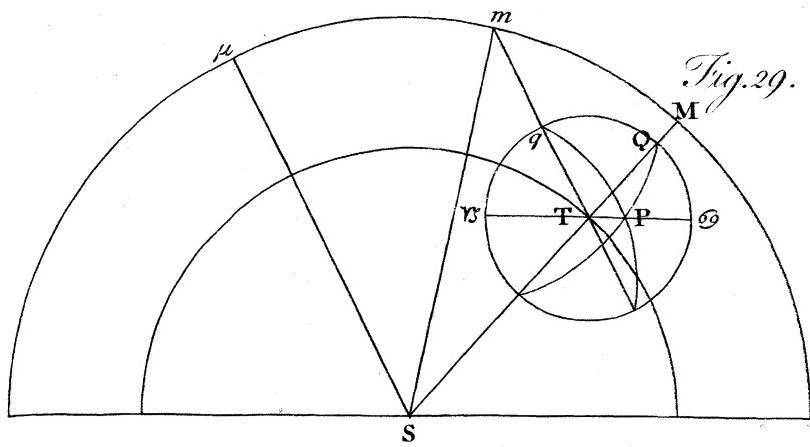
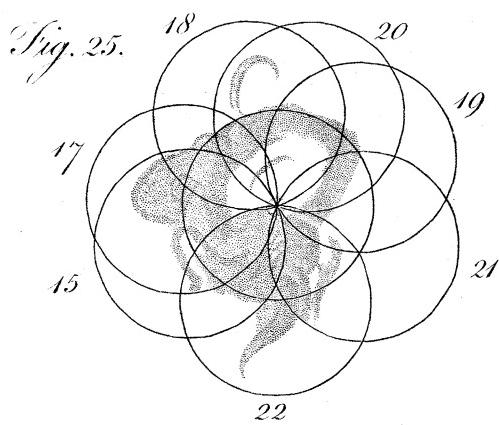


Fig. 28.

Track of the bright South polar spot on Mars,
in October 1783.



The largest of the two stars on which the above observations were made cannot exceed the twelfth, and the smallest the thirteenth or fourteenth magnitude; and I have no reason to suppose that they were any otherwise affected by the approach of Mars, than what the brightness of its superior light may account for. From other phænomena it appears, however, that this planet is not without a considerable atmosphere; for, besides the permanent spots on its surface, I have often noticed occasional changes of partial bright belts, as in fig. 1. and 14.; and also once a darkish one, in a pretty high latitude, as in fig. 18. And these alterations we can hardly ascribe to any other cause than the variable disposition of clouds and vapours floating in the atmosphere of that planet.

Result of the contents of this paper.

The axis of Mars is inclined to the ecliptic $59^{\circ} 42'$.

The node of the axis is in $17^{\circ} 47'$ of Pisces.

The obliquity of the ecliptic on the globe of Mars is $28^{\circ} 42'$.

The point Aries on the martial ecliptic answers to our $19^{\circ} 28'$ of Sagittarius.

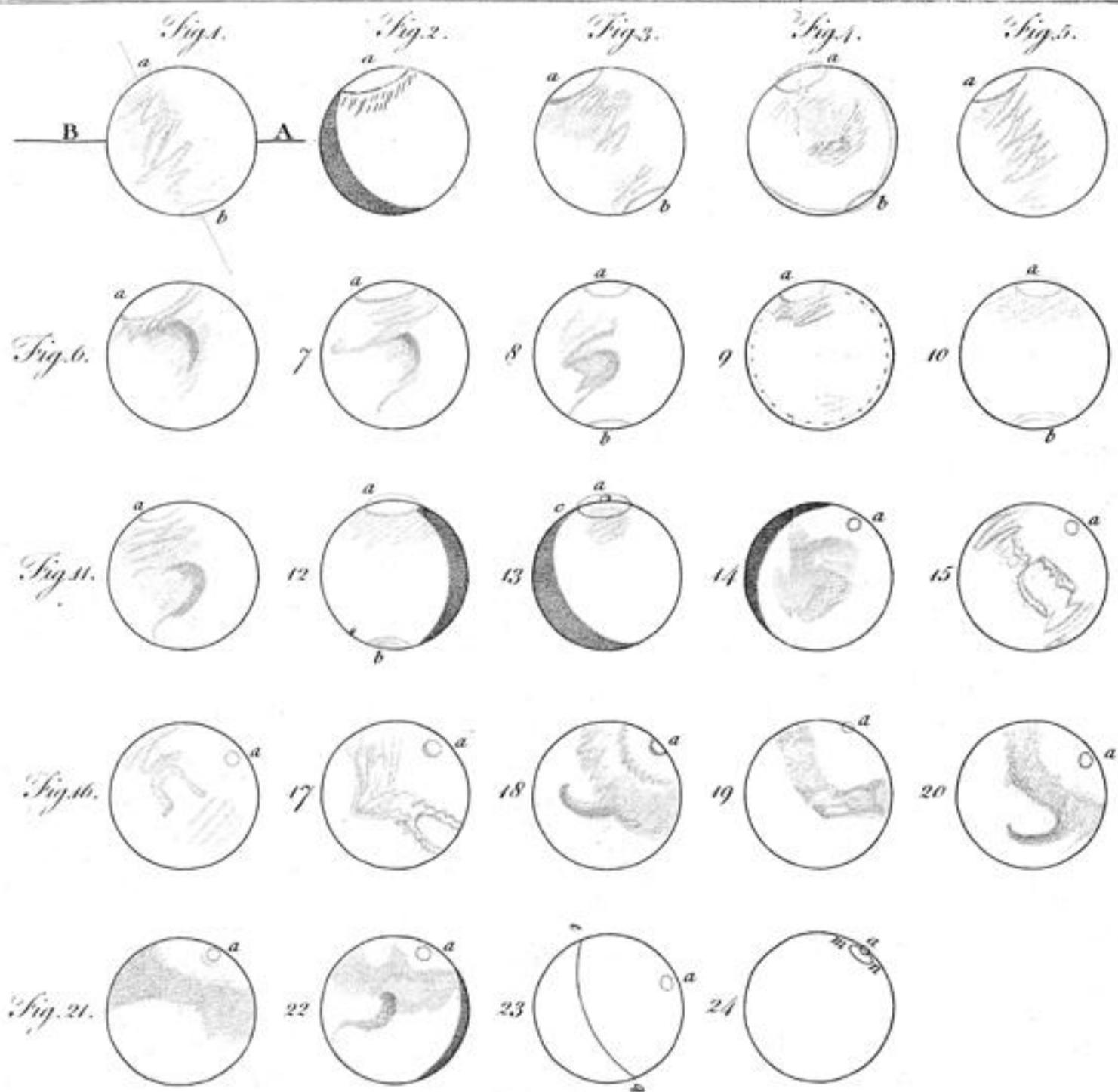
The figure of Mars is that of an oblate spheroid, whose equatorial diameter is to the polar one as 1355 to 1272, or as 16 to 15 nearly.

The equatorial diameter of Mars, reduced to the mean distance of the earth from the sun, is $9'' 8'''$.

And that planet has a considerable but moderate atmosphere, so that its inhabitants probably enjoy a situation in many respects similar to ours.

Datchet, Dec. 1, 1783.

W. HERSCHEL.



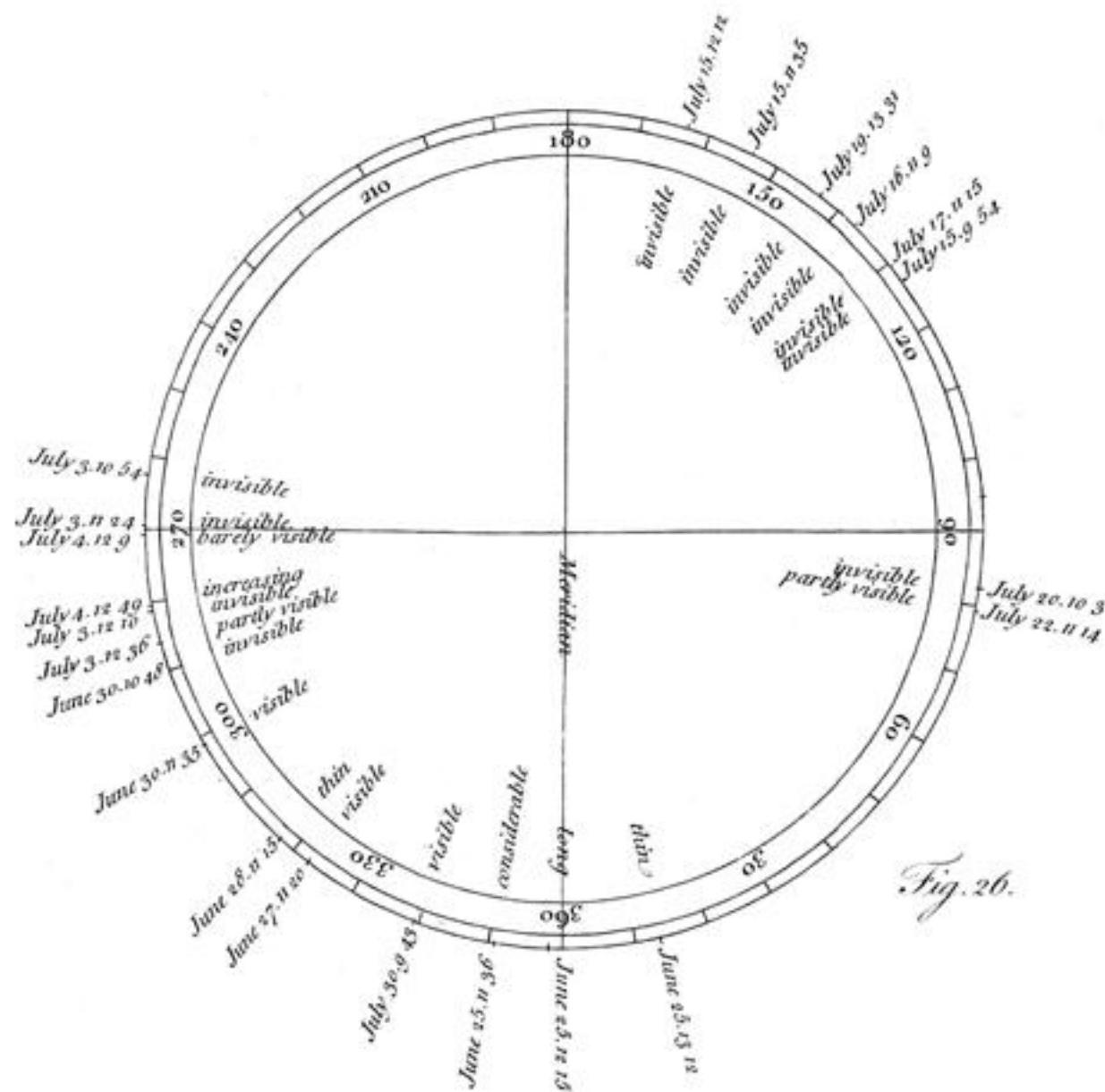
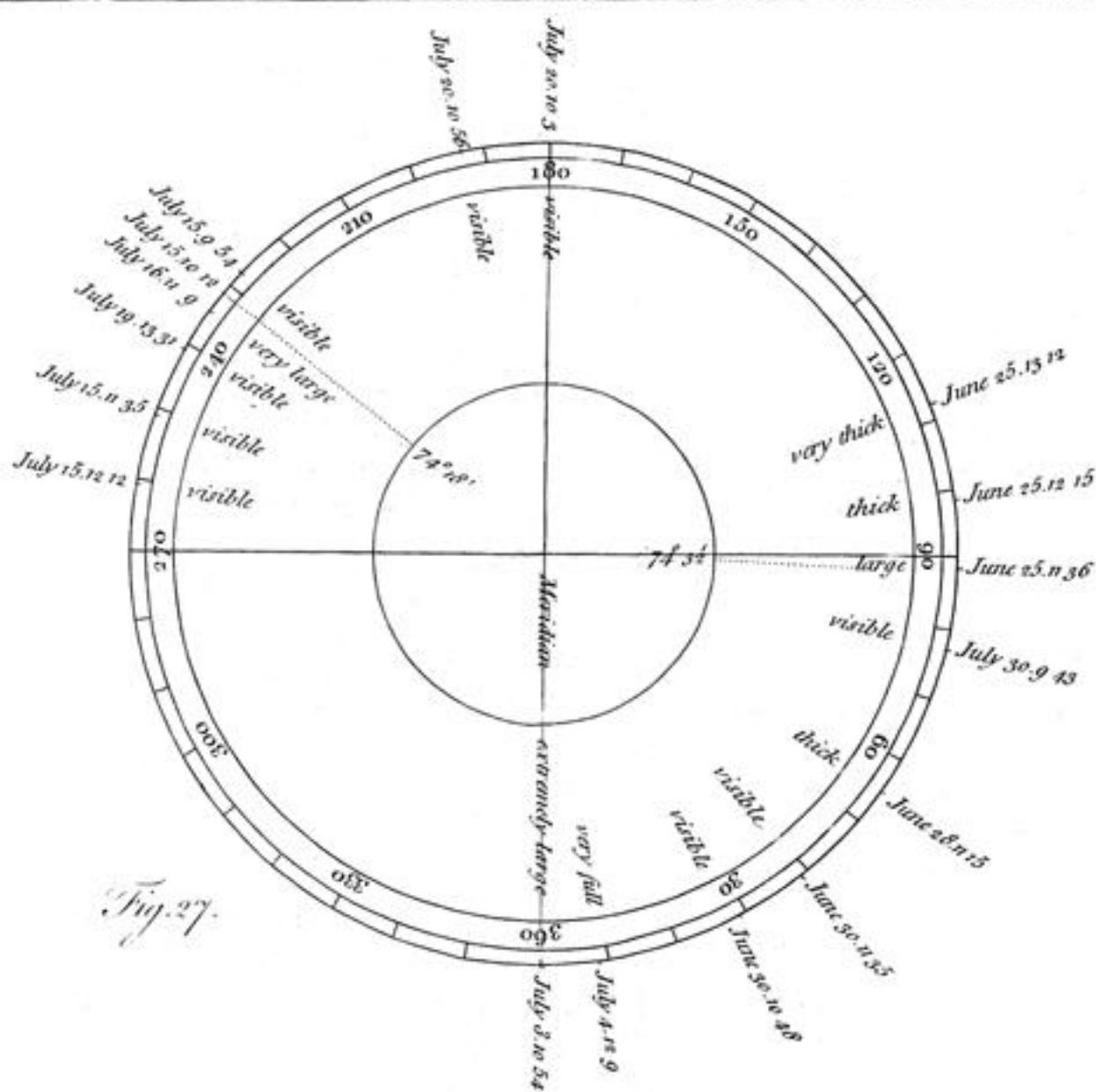


Fig. 26.

*Track of the bright north polar spot on Mars,
in June & July 1781.*



*Track of the bright south polar spot on Mars,
in June & July 1781.*